Academic Achievement Enhanced by Personal Digital Assistant Use

Alexander Bick

Millburn High School

Millburn, New Jersey

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1. Introduction

Research during the past decade suggests that integrating computing technology in general, and mobile computers in particular, into the educational environment has positive affects (National Research Council, 2002). To obtain higher academic achievement, a projected six billion dollars were spent on educational technology in the United States during the 2003-04 school year, adding to the approximately sixty billion dollars spent since 1991 (Johnson, 2004). The United States Congress in 2001 recognized the potential for educational technology to enhance learning and set aside federal funds for schools that wish to purchase educational technology that has been proven through empirical "scientifically rigorous" research. Yet, scientific research remains to be done in order to determine what technology improves student academic achievement as required by the No Child Left Behind Act (Bush, 2002).

In 1998, three landmark studies found that laptop computers increased student achievement. Specifically, students who utilized mobile laptop technology as a learning tool were found to think at higher levels, work together more and become much more involved in the learning process. (Belanger, 2000). Fung (1998) wrote of a "paradigm shift" towards increasingly portable computing in education. Handheld devices, including cell phones, Pocket PCs™ and Palm Pilots™ represent the next logical step in this progression towards increasingly mobile computers. These devices come in many forms and capabilities. Collectively these devices are known as Personal Digital Assistants (PDAs). The current generation of PDAs (including Palm Pilots™ and Pocket PCs™) have the same raw computing power as the laptop computers of several years ago (Dieterle, 2004). PDAs can be used for a variety of functions: to manage work or study schedules, to record and store data, and to access and disseminate information (Waycott, 2003). PDAs can run many of the same applications as laptops. For

example, Pocket versions of Microsoft Word® and Excel® and the Internet Explorer® browser are available for PDAs.

Analogies have been made between the function of laptops and PDAs (Soloway, 2001). Current research involving PDAs has focused on specific applications where PDAs can be used, for example with distributed wireless simulations (Repenning, 2003). Other research has evaluated the effectiveness of PDAs for specific tasks. PDAs have been found to increase the efficiency of medical students in their primary clerkship (Kurth, 2002). Additionally, the effectiveness of PDAs has been demonstrated in the business environment (Devi, 2002). Until now, no long-term study has been reported in literature with the goal of determining the effects of using a PDA at the High School level (Bick, 2005a).

This project seeks to determine if there is a link between PDA usage and standard measures of academic achievement operationally defined as Grade Point Average (GPA) (Hu, 2002) and subject test scores. This project consists of three separate investigations. The first examines the impact of PDA usage on student GPA. The second examines the impact of PDA participatory simulation software on science test scores. The third examines the impact of a PDA intelligent tutor on algebra test scores. The overall hypothesis is if a PDA-enabled student (one from the treatment group) uses a PDA then the relative change in their achievement during the study period will be positive when compared to the change in achievement of the control group.

Currently, schools are spending thousands of dollars on mobile carts containing laptops for in-class use. For the cost of a cart and 25 laptops, about $25,000, a school could potentially purchase a PDA for 250 students, increasing student access to technology and possibly saving money (Bick, 2005b). Under the No Child Left Behind Act, schools can apply for federal grants for technology that is of proven value to increasing academic achievement. For those school

systems seeking federal funding for PDA implementations, the results of this research satisfies the requirements set forth in the No Child Left Behind Act.

2. Study of PDA-Enabled Students and General Academic Achievement

This study examined the impact of semester-long PDA usage on general high school academic achievement as measured by GPA. During the five trials which were conducted over a two and a half year period, 50 randomly selected students, comprising the treatment group, each used a PDA for five months. The null hypothesis is: if a student uses a PDA then there will be no relative change in their GPA during the study period of one semester when compared to the change in the GPA of the control group which is made up of all other students in the participant group's grade and their prior performance.

2.1 Method

The first step was to obtain necessary Millburn high school administration and institutional review board approval. A census of high school students was used to determine that the number of students currently possessing PDAs in the school was statistically insignificant. The entire population (defined as a grade or a graduating class) not selected to receive PDAs was considered the control group. A simple random sample of second semester freshmen and first semester sophomores[1] determined which students would be offered the fifteen PDA devices. After all necessary parties signed consent forms, students were given Microsoft Pocket PC PDAs (Specifically: Compaq iPaq 3850, HP Jornada 564 & Audiovox Thera) to use for a semester-long trial period. The Pocket PCs were loaded with productivity software (including Pocket Word, Pocket Excel, Pocket ClassPro and Calculator), custom usage tracking software and survey software (See Appendix I for more details). The participants were provided with product

[1] Second semester freshmen and first semester sophomores were selected because these students are all required to take the same courses.

manuals but were given no training or specific instruction on how to use the devices. Participants were asked to upload usage data several times during the semester and occasionally asked to comment about their Pocket PC experience. At the end of the semester, the students returned the Pocket PCs. Anonymous information about the participant and control group's academic performance was received from the school administration.

T-test and histogram were used to ensure the simple random sample of students was a representative sample. The change in PDA-enabled student performance was then compared to the change in performance of the rest of the students in the population and the relative change was then analyzed. For example, if the participants' achievement increased 18% and the control population increased 10% the relative increase would be 8%. The participants' performance was then compared to their previous performance to confirm that the sample was representative. Finally, a t-test was used to ensure that the change in achievement was statistically significant.

PocketSurvey, a multi-tiered application, enabled participants to easily respond to questions and submit feedback on their experience on PDAs (Appendix I). Students were asked to respond to survey instruments on approximately a bi-monthly basis. The data was used primarily as anecdotal support to complement the quantitative data collected.

2.2 Data

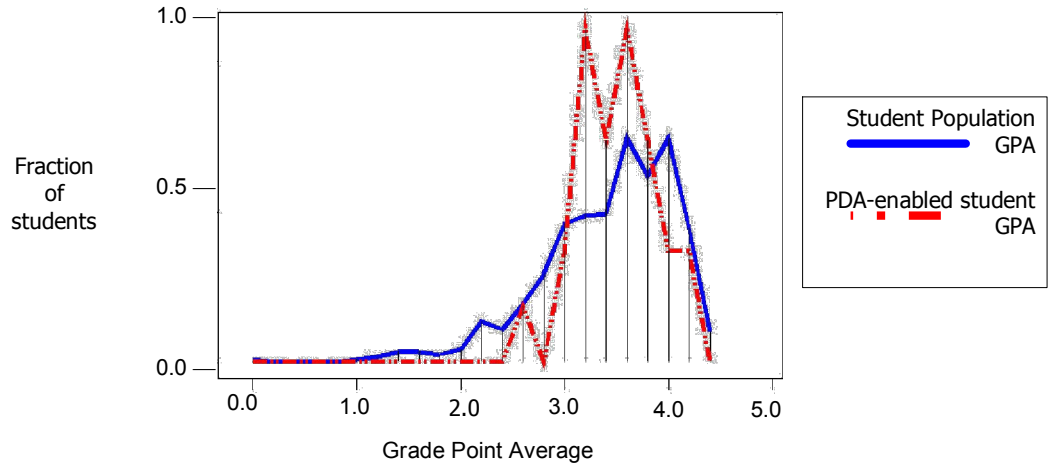
Table 1: Study Demographics

Trial	Students in Population	PDA Enabled Students	Trial Dates
1	301	9	1/23/2003- 6/22/2003
2	303	8	9/8/2003-1/26/2004
3	295	9	1/26/2004-6/19/2004
4	295	11	9/7/2004- 1/19/2005
5	298	13	1/19/2005- 6/24/2005

50 randomly selected students comprised the sample of PDA Enabled Students

Given the sample and population size, the study was conducted at the 98% confidence level.

Graph 1: Pre-Trial Density Plot of PDA-Enabled Student GPA and Population GPA



Graph 1 is a set of density distributions comparing the PDA-enabled participants in each trial to the population before the study occurred. The plot demonstrates that the sample is representative.

Table 2: Normalized[2] GPA Change of PDA Enabled Students and the Population

Trial	% change in PDA-enabled student GPA during trial	% change in Population's GPA during trial	% difference between change in PDA users and Population GPA
1	08.86	-04.65	13.51
2	00.57	06.80	-06.23
3	24.47	-09.41	33.89
4	12.22	01.82	10.40
5	05.66	-08.19	13.85
Average	10.36	-2.73	13.08

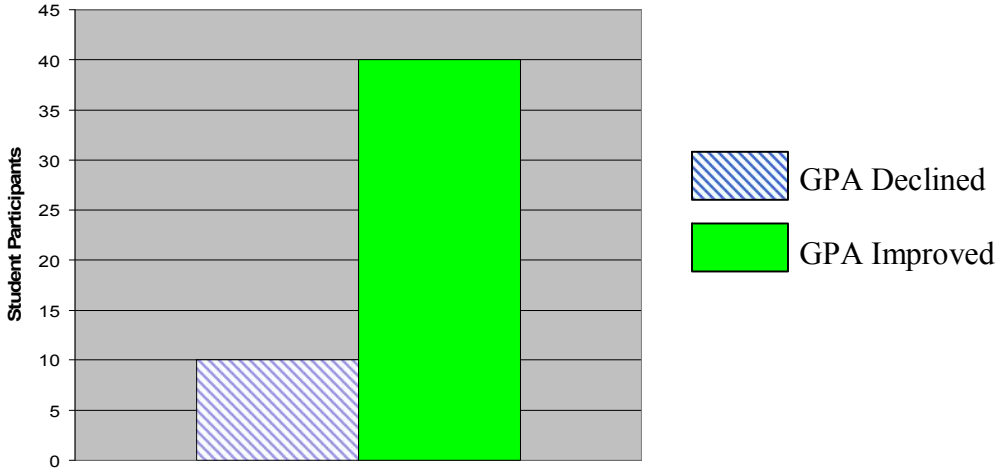
Table 3: Ordered List of Most Frequently Used Programs

1.	Pocket Calendar
2.	Pocket Tasks
3.	Microsoft Word
4.	Pocket Class Pro
5.	Pocket Contacts
6.	Windows Media Player
7.	Games – (specifically Solitaire, Cubical Chaos, Pocket Chess, Jawbreaker)

[2] Normalization was accomplished using the z-score formula : $\frac{x_i - \bar{x}}{\sigma}$

8.	Internet Explorer
9.	Calculator
10.	Microsoft Excel

Graph 2: Summary of PDA-enabled student GPA change



Graph 2 displays the relative improvement seen by individual PDA-enabled students. A majority of the students increased their performance relative to their prior performance.

2.3 Discussion

Analysis of the data indicated that a clear association existed between PDA usage and higher academic achievement as measured by GPA after one semester of usage. Thus, the data disproved the null hypothesis, which stated that there would be no change in PDA-enabled student achievement. The effect was demonstrated by the 50 student participants over the five semester-long study period (Table 1). The density plots (Graph 1) demonstrate that the simple random sample of students was generally a representative sample of the population. The GPA distribution of the population was somewhat skewed, but this probably resulted from the weighted GPA calculation which assigns higher averages to students in honors classes. The t-test further confirmed that the randomly selected treatment group was statistically indistinguishable from the population before the trial began.

The normalized average performance increase is displayed in Table 2. The table indicates that in every trial the average performance change of PDA using students was positive. Variability is seen in the individual trials because both positive and negative outliers easily affect the small sample size. The average increase is an accurate measure of percent change in GPA because it is outlier resistant. The average increase differential between PDA-enabled students and the population was 13.08%. This is the equivalent of changing from a B+ student at the beginning of the semester to an A- student at the end of the semester.

The "second semester slump" trend – an emic expression referring to the second half of the school year– can be seen within the data summarized in Table 2. During the second semester, students tend to neglect their studies and become more careless with assignments (Groove & Wasserman, 2004). Hence, in trials 1, 3 and 5, the population generally had a highly negative change in grade point average. However, during all three trials, the PDA using students increased their GPA significantly over the "second semester slump" period. This suggests that PDAs probably assisted the students in keeping track of their assignments and were useful as organizational tools. This possible explanation is supported by usage tracking data.

To determine student usage of the PDAs, rudimentary tracking software was designed that recorded every time a student opened a program (See Appendix I). The software did not record accurately the amount of time a student spent using a given program due to the PDA programming architecture. Also, due to the nature of Pocket PC flash memory, the data files were erased if a participant forgot to charge their Pocket PC. As a result, the numbers of times the programs were accessed is not reported because the data are incomplete. The data were sufficient to obtain a general list of programs and how frequently the programs were used. Subsequently, the data collection problem was corrected through the use of automatic data

transmission over the internet.

The usage tracking data was surprising. Many members of the high school faculty predicted that students would primarily play games on the PDAs during instructional time. The usage tracking data suggests that games were only the seventh most frequently accessed program on the PDA. As the data summarized in Table 3 shows, the PDA's organizational functions were often used. Specifically Pocket Calendar and Pocket Tasks, programs that are useful in all academic classes for keeping track of short and long-term assignments, were the most frequently used programs.

The PDA enabled students' GPA improvement compared to their prior performance validates that the PDAs improved achievement and that the PDA-enabled participants were a representative sample. Overall, 80% of PDA-enabled participants improved their GPA over the course of the study. (Graph 2) On average PDA-enabled students' GPA increased 10.35 % each trial, which is statistically similar to the 13.08% improvement relative compared to the population. The t-test confirmed that the PDA-enabled students' improvement relative to both their prior performance and the population was statistically significant at the 95% level.

Survey data shows that participants generally had very favorable experiences with their Pocket PC devices. Participants commented that they felt the devices were very helpful in staying organized and keeping track of their assignments. Comments included, "The PDA is small enough to carry with you everywhere", and "My PDA was great for keeping track of my schedule." Many participants were very reluctant to return their Pocket PC devices. Several stated, "I wish I could keep my PDA." As seen in Table 1, every trial had less than the fifteen students selected through the simple random sample. In each trial at least one participant decided to withdraw from the study and several declined to participate. The reasons for not participating

included “I’m afraid I’ll break it” to “My current student planner and notebook work fine” and “I have no need for the device.”

3. Study of PDA-Enabled Participatory Simulation and Biology Achievement

Participatory simulations (PS), activities made possible with handheld devices that teach by embedding learners in life-size simulations, have been shown to positively affect student learning (Klopfer 2005). This project sought to determine if PDA PS increased academic achievement. Additionally, this project sought to determine if learning style affected the efficacy of the participatory simulation. The null hypothesis was PDA PS would not affect academic achievement and the learning style variable would be independent of efficacy.

3.1 Method

To create the “Live Long and Prosper” PS study software, a 2,000-line program using the C# language was written which incorporates the MIT “Thinking Tags” participatory simulation protocols (Klopfer, 2004). This software was loaded on 20 Pocket PCs and used by 78 high school students. (See Table 4) Five 45-minute trials were conducted.

Players in the PS are told to live as long as possible and reproduce. A player’s ability to survive and reproduce is influenced by their one to eight gene genome which is displayed. Each of the genes stands for a trait. The shading of the genes somehow stands for homozygous recessive, homozygous dominant and heterozygous at that position. The players choose other participants with whom to “mate” (via the infrared port) and through selective mating gain the traits that allow them to “live long and prosper”. Students learn genetics and the scientific method by embedding themselves in this inquiry-based simulation of a fruit fly life cycle.

Participants took Klopfer’s (2005) previously validated pre-trial and post-trial assessments to evaluate their knowledge of the material presented by the PS. Participants’

learning styles were assessed using a version of the Felder and Soloman Index of Learning Styles (1988).

3.2 Data

Table 4: Participatory Simulation Demographics

Biology Level	Male	Female	Total
Standard	17	14	31
Honors	12	15	27
Advanced Placement	11	9	20

All 78 participants were High School Students (Ages 14-16)

Table 5: Two-sample T-test comparison of Pre-Test score vs. Post Test Score

	Mean	StDev
PostTest	0.735	0.272
PreTest	0.409	0.266
Δ Test Score	0.326	

95% Confidence Interval for difference: (0.2155, 0.4361)

T-Test of difference = 0 (vs not =): T-Value = 5.87 P-Value = 0.000

Table 6: Selected responses from post-participatory simulation response questions

Table 6a: Response by Class Level: I thought the technology was fun

Level	Standard	Honors	Advanced Placement
Mean	4.05	3.63	4.13
Std. Dev	0.97	1.3	0.74

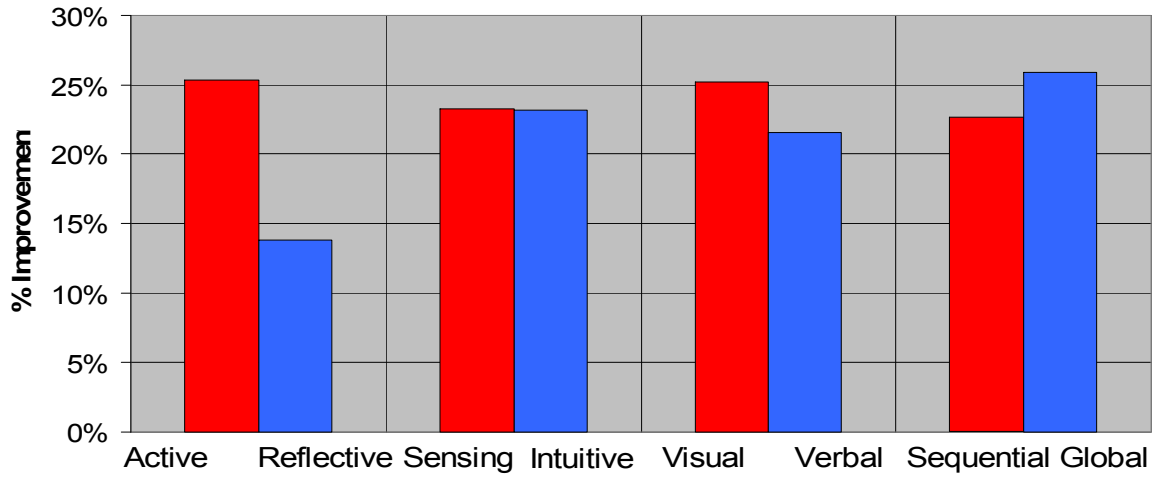
Likert Scale: 1-strongly disagree 3-Neutral 5-strongly agree

Table 6b: Response by Gender: I thought finding the patterns in the data was easy

	Male	Female
Mean	3.286	2.850
Std. Dev	1.240	1.195

Likert Scale: 1-strongly disagree 3-Neutral 5-strongly agree

Graph 3: Percent Improvement by Felder and Solomon Learning Style



This graph illustrates the pre-test compared to post test percent improvement grouped by learning styles. The greatest difference was found in the active compared to reflective learners.

3.3 Discussion

The data clearly disprove the null hypothesis, indicating that PDA participatory simulations had a statistically significant positive impact as teaching tools. A 95% confidence interval shows there was between a 21.5% and 43.4% difference in pre-trial and post-trial exam scores (Table 5). Students of all academic levels reported enjoying the participatory simulation (Table 6a). No significant difference was found between genders in pre-test/post-test improvement. However, a post-trial survey found a statistically significant difference between genders with respect to finding patterns. Boys reported that they found patterns more easily than girls (Table 6b).

A student's learning style, as determined by the Felder and Solomon Index (1988), was found to affect both the achievement increase resulting from the PDA simulation and the perception of PDAs as a teaching tool. The Felder and Solomon classification describes each person in four dimensions. Each dimension has two mutually exclusive qualities. In particular, a person is either active or reflective; sensing or intuitive; visual or verbal; and sequential or

global. For example, a person might be classified as a reflective, sensing, visual, global learner. Active learners improved 12% more than reflective learners when comparing pre/post-test scores. Visual learners improved 6% more than verbal learners on the pre/post-test assessment (Graph 3).

4. Study of PDA Location-aware Intelligent Tutoring Software and Achievement

Intelligent tutoring software (ITS) is defined as educational software containing an artificial intelligence component. The software tracks students' work, tailoring feedback and hints along the way. By collecting information on a particular student's performance, the software can make inferences about strengths and weaknesses, and can suggest additional work. ITS has been widely deployed on desktop and laptop systems in secondary schools and shown to increase achievement (Schofield 1994). Prior to this study no ITS existed on any PDA platform. The ITS created for this study, named OTIS (On Target Instructional Software), took advantage of the uniquely portable properties of the PDA to tailor lessons and problems to the student's location in the real world. For example, OTIS-enabled students could study algebra at the mall or the movies. The null hypothesis was that students using OTIS would show no change in achievement. 9 students used a PDA version of OTIS while 11 completed normal Algebra I exercises.

4.1 Method

OTIS was written in Visual C#.NET. One class of 20 under-achieving algebra students was selected to test the software. Nine randomly selected students were given Pocket PCs with OTIS installed. The remaining 11 students completed standard worksheets for homework. Students used OTIS every night for 20 minutes and an hour on the weekend for two weeks to learn basic algebraic concepts. OTIS asked users about their current location and gave students

application problems dealing with the student's location. For example, if the student indicated that he was shopping at the grocery store, OTIS would ask users to create and apply an algebraic formula to identify the best carton of orange juice to buy. Student engagement was measured through periodic survey questions.

4.2 Data

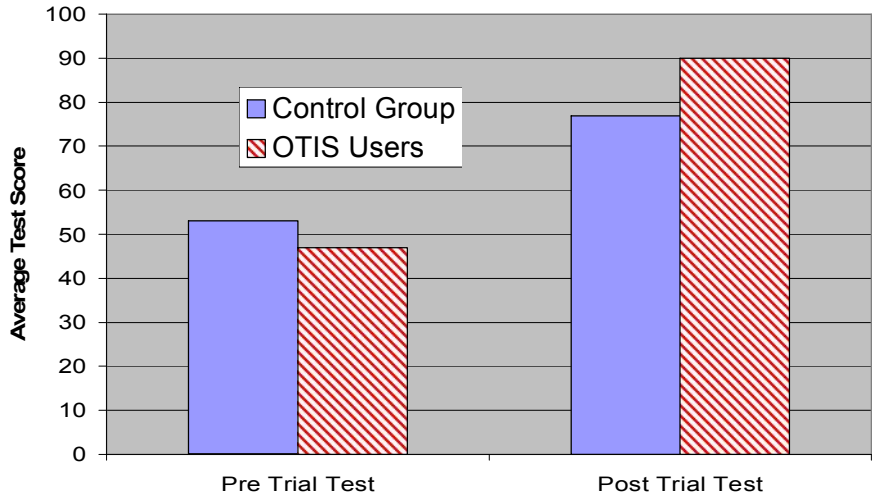
Table 7: Two-sample T-test comparison of OTIS Users vs Non-users at end of trial period

	Mean	StDev
OTIS Users	90.0%	7.56
Control Group	77.1%	15.9

95% Confidence Interval for difference (02.35, 23.36)

T-Test of difference = 0 (vs not =): T-Value = 2.56 P-Value = 0.019

Graph 4: OTIS Users Improve Significantly



4.3 Discussion

The data clearly reject the null-hypothesis showing increased achievement. Students from the control group and the group using OTIS performed similarly on the pre-trial test of content knowledge (Graph 4). Following four weeks of in-class instruction and out of class homework, the group of students that were equipped with the OTIS participatory simulation scored statistically significantly better than the control group on the post trial test (Table 7). Student

time on task between the control group completing traditional homework exercises and the students using OTIS was equivalent. Students using OTIS responded favorably to the scaffolded hints offered by the tutor. One student wrote, "I like how when I did not complete a math problem, it [OTIS] gives you a hint on how to solve the problem." The real-world relevancy was also appreciated by the OTIS-enabled students. Many commented that they liked the word problems. The greatest complaint from the OTIS users was the software's occasional mistakes recognizing student handwriting.

5. Conclusion

This four-year study clearly indicates that PDA device usage positively affects academic achievement. PDAs have been shown to increase achievement in three different areas. First, PDAs statistically significantly increase student GPA within a semester. The affect is statistically significant as measured by the t-test at the 98% confidence level. The results are verifiable through repeated testing, as demonstrated by the consistency of the data through five trials. The usage data indicate that students were using the organizational features of the PDA as well as the entertainment features. Prior education research has found that students with increased organization achieve more (Bakunas, 2001).This is one possible explanation for the increase in student achievement by PDA-enabled students. Participants were using a new tool (the PDA) in an old way (as an assignment pad). Since the new tool is more effective, efficiency increases and achievement increases.

Second, subject specific achievement increases as is demonstrated by the participatory simulation software that increased student achievement in biology. Students using the participatory simulation learned a significant amount from the simulation and enjoyed the method of learning. The analysis of data by learning style can be highly useful to teachers in

determining whether the simulation is a suitable teaching tool for their class.

Third, PDA devices are suitable platforms for intelligent tutors. OTIS, the first PDA-based intelligent tutor, was written and tested on a small-scale as a proof of concept. Students using the intelligent tutor significantly increased their Algebra I knowledge as reflected by the change in pre and post-trial test scores compared to the control group.

The OTIS tutor has two advantages over traditional intelligent tutors. First, the tutor was written for the PDA platform, which is far more economical than the PC platform. While a full-scale comparison of PDA and desktop intelligent tutor software should be conducted to better determine the efficacy of each, the improved achievement of OTIS-enabled students is similar to the reported improved achievement in PC-based intelligent tutor studies. School districts wishing to implement intelligent tutors could save money or increase access to the software by purchasing PDAs rather than PCs. Second, the tutor was uniquely portable and incorporated location-based information in a realistic way. A study should determine how this affects student engagement and achievement compared to traditional desktop-based intelligent tutors.

OTIS and the Participatory Simulation demonstrate that when a new tool is used in a new way achievement increases significantly. These results clearly support Soloway's (2001) assertion that "Each and every child should be provided with a $100 handheld device." These three investigations, when combined, provide a glimpse of the effectiveness and potential usefulness of a large scale, long-term implementation of PDA devices.

This research provides teachers, administrators, and government officials with data suitable for more trustworthy reallocation of technology and programming budgets. The improvement resulting from PDAs, costing one-tenth the price of laptops, is greater than the achievement increase found by the Rockman (1998) study of laptop computers. This suggests

that schools with the goal of using technology to increase student achievement and access to technology should strongly consider purchasing 250 PDAs rather than a cart and 25 laptops.

Under the No Child Left Behind Act, schools can apply for federal grants for technology that is of proven value to increasing academic achievement. This research provides necessary "empirical" proof and supports schools that want to apply for federal funds for Personal Digital Assistant purchases.

Several hurdles remain before PDA usage can be effectively implemented in schools. First, there is a misperception that technology is a panacea that cures academic achievement woes. Dede (1995) cautions that "evolution of learning devices won't be a "silver bullet" that magically solves all problems of education. Also more work needs to be done to determine the appropriate infrastructure that would maximize the success of high school PDA implementations (Carney, 2004). Teachers need to be trained on the use of handheld computers and made aware of the handheld resources available to them (Staudt, 2000). Attention must be paid to maintaining handheld computers. The training of tech-support staff is critical, especially when the devices are first distributed (Pownell, 2001).

There are many areas of Personal Digital Assistant research that have not yet been explored. Attitudinal tests should be implemented to determine if the presence of the PDA affects perception of the learning environment. The correlation between amount of use on specific PDA programs and GPA should be established. Studies should examine how certain geographic and socio-economic variables affect PDA usage and achievement. Since the high school studied was a middle-class suburban district, achievement increases may be different in different geographical and socio-economic areas. Also, a large-scale comparison of PDAs and laptop computers should be undertaken to determine the relative efficacy of each device.

Clearly, this research demonstrates that personal digital assistants have the potential to dramatically improve high school academic achievement. Furthermore, this research suggests that an immediate reallocation of a large portion of the $6 billion per year national educational technology budget is necessary.

6. Acknowledgements

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Appendix I: Summary of Novel Software Created by Bick and employed by Project

Software available online at Http://www.millburn.org/science/pda

uTrack

Description: First Pocket PC device usage tracking software.

Purpose: Prior to the creation of this application for the purposes of determining student usage of their PDAs, no Pocket PC usage tracking software was publicly available. The current version automatically sends the usage data over the internet. This minimizes data loss. The software is useful to both corporations and schools that deploy Pocket PCs.

Currently in use by: Louisiana State University

Language/ Platform: C#/ Pocket PC .Net Compact Framework

Lines 200

PocketSurvey

Description: First three tiered survey system software that enables non-technical user to create surveys& upload the survey over the internet to a server, automatically downloads the survey, alerts the user and automatically uploads the completed survey over an internet web service

Purpose: The survey software consisting of a PC application, Pocket PC application and Windows server application was built for two reasons. First, it enabled the researcher to quickly and accurately collect qualitative information useful for this study. Second, the No Child Left Behind Act requires schools to constantly evaluate the effectiveness of their technology programs. This software enables school administrators, teachers and researchers to easily collect and evaluate needed data.

Currently in use by: Millburn High School, NJ; Chicago Public School 6, IL

Language/ Platform: C#, SQL, SOAP/ Windows Server 2003, Internet Information Server, SQL Server, Windows XP, Pocket PC .Net Compact Framework

Lines: 30000

Live Long and Prosper: Pocket PC

Description: First Pocket PC participatory simulation software that teaches genetics.

Purpose: To teach genetics in an inquiry based way on an economical platform

Currently in use by: Massachusetts Institute of Technology

Language/ Platform: C#/ Pocket PC .Net Compact Framework

Lines: 2000

On Target Instructional Software (OTIS)

Description: First PDA intelligent tutor software that teaches math/ PC software for teachers to design custom curriculum material for the tutor.

Purpose: Until the creation of OTIS, Intelligent tutors (reported in the literature and commercially available) were limited to the desktop platform. The Pocket PC platform is less expensive and more portable.

Currently in use by: Antioch University

Language/ Platform: C#/ Pocket PC .Net Compact Framework & Windows XP

Lines: 4000